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Brief communication: What do we need to know? Ten questions about climate and water challenges in Berlin-Brandenburg

Pedro Henrique Lima Alencar[1,*], Saskia Arndt[2], Kei Namba[2], Márk Somogyvári[3], Frederik Bart[4], Fabio Brill[3], Juan Dueñas[6,7], Peter Feindt[3], Daniel Johnson[5], Nariman Mahmoodi[11,12], Christoph Merz[11], Subham Mukherjee[18], Katrin Nissen[19], Eva Paton[1], Tobias Sauter[13], Dörthe Tetzlaff[14,15,3], Franziska Tügel[16,17], Thomas Vogelpohl[3], Stenka Valentinova Vulova[8,9], Behnam Zamani[10], and Hui Hui Zhang[13]

[1]Chair of Ecohydrology, Institute of Ecology, Technical University of Berlin, Ernst-Reuter-Platz, 1, 10578 Berlin, Germany
[2]Chair of Landscape Planning and Development, Technische Universität Berlin, Berlin, 10623, Germany
[3]Humboldt-Universität zu Berlin, IRI THESys, Berlin, Germany
[4]Chair of Climatology, Technische Universität Berlin, Berlin, Germany Rothenburgstraße 12, 12165 Berlin
[5]Professor for Value-Based Forest Economy Eberswalde University for Sustainable Development Alfred-Möller-Str. 1, 16225 Eberswalde, Germany
[6]Institute of Biology, Freie Universität Berlin, 14195 Berlin, Germany
[7]Berlin-Brandenburg center of Advanced Biodiversity Research, 14195 Berlin, Germany
[8]Chair of Smart Water Networks, Technische Universität Berlin, Straße des 17. Juni 135, Berlin, 10623, Germany
[9]Geoinformation in Environmental Planning Lab, Department of Landscape Architecture and Environmental Planning, Technische Universität Berlin, Straße des 17. Juni 145, 10623 Berlin, Germany
[10] Water Quality Engineering, Technical University of Berlin, Berlin, Germany
[11]Department of Hydrogeology, Freie University Berlin, Berlin, 12249, Germany
[12]Department of Lowland Hydrology and Water Management, Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, 15374, Germany
[13]Geography Department, Humboldt-Universität zu Berlin, Berlin, 12489, Germany
[14]Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
[15]Geography Institute, Humboldt University of Berlin, Berlin, Germany
[16]Department of Water Resources, Faculty of Geo-Information Science and Earth Observation, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands
[17]Water Engineering and Management, Faculty of Engineering Technology, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands
[18]Physische Geographie, Freie Universität Berlin, Malteserstr. 74-100, Haus H, Raum H 137, 12249 Berlin
[19]Klimadiagnostik und meteorologische Extremereignisse, Freie Universität Berlin, Carl-Heinrich-Becker-Weg 6-10 12165 Berlin

Correspondence: Pedro Henrique Lima Alencar (pedro.alencar@campus.tu-berlin.de)

Abstract. As climate change escalates, the Berlin-Brandenburg region faces new challenges. Climate change-induced extreme events including droughts, heatwaves, and floods, are expected to cause new conflicts to emerge and aggravate existing ones. To guide future research, we engaged a transdisciplinary academic community of experts to co-develop a list of key questions on these climate and water challenges in the region. Our findings highlight the urgent need for integrated and participatory research approaches. We expect this list of key questions to provide a roadmap for scientists and policymakers to foster actionable knowledge production to address climate and water challenges in the region.

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1 Introduction

As climate change accelerates, the number and complexity of associated problems in the agriculture, water, health, infrastructure and energy sectors often exceed the time needed and resources available to address them effectively (IPCC, 2022; UNESCO, 2020). To ensure measurable progress in adapting systems to future challenges, it is crucial to identify and prioritise the most pressing climate and water-related issues. As a community of scientists, we can guide this focus by establishing priority lists of problems or questions, a strategy that has worked well in the past. In 1900, the mathematician David Hilbert presented the mathematical community with a list of 23 fundamental problems that profoundly shaped the development of the discipline. Inspired by this approach, frameworks such as the 'Twenty-three unsolved problems in hydrology' paper (Blöschl et al., 2019) have contextualised research and catalysed innovation across disciplines.

Motivated by this concept, we aim to apply a similar methodology to one of Germany's most vulnerable regions to the impacts of climate change: Berlin-Brandenburg. As one of the driest and warmest areas in Germany (558 mm mean precipitation compared to 789 mm for Germany and 8.7 °C mean temperature compared to 8.2 °C for Germany for the reference period 1961-1990) (DWD, 2022), with predominantly sandy soils, the drought-sensitive region of Berlin-Brandenburg faces significant challenges under climate change (Reyer et al., 2023). The region is experiencing increasingly extreme climate patterns, including long periods of drought, more frequent heat waves, and heavy rainfall events (Paton et al., 2024; Pohle et al., 2024; Luo et al., 2024). These climate extremes place increasing stress on regional water resources to be able to meet the needs of the agriculture-forestry sectors, water provision for all water users and human health, while also challenging many regional ecosystems (Conradt et al., 2023).

Compounding these climate-induced pressures are the consequences of the German gradual phase-out of lignite mining by 2038, particularly evident in the Lausitz region in southeast Brandenburg. While this transition represents a necessary step towards national carbon dioxide reduction, it introduces significant socio-economic and environmental challenges in the wider region. It will not only impact regional employment and economic stability associated with the lignite mining, energy, and automobile industries but will also disrupt established water management practices. The Spree and post-mining landscapes such as reservoirs and artificial lakes have been supported for over 60 years by a constant, if unsustainable, inflow of sump water from this lignite mining (Uhlmann et al., 2023; Chen et al., 2023). Downstream, this artificially increased discharge benefits the wetland areas of the Spreewald, a critical area for nature conservation, cultural activities and tourism, and the water supply for the densely populated urban area of Berlin (Uhlmann et al., 2023).

To address these interconnected challenges, it is essential to advance knowledge and research on Berlin-Brandenburg's adaptability to climate change, which can be viewed as representative for other drought-sensitive, heavily anthropogenically changed, extensive lowland regions. The interplay between ecological vulnerabilities and socio-economic transitions underscores the need for inter- and transdisciplinary approaches. This paper explores how science can contribute to these efforts by identifying future research priorities that bridge gaps between science, policy, and practice, and outline a more adaptive and cohesive strategy for a resilient and sustainable Berlin-Brandenburg region.

https://doi.org/10.5194/egusphere-2025-428
Preprint. Discussion started: 4 April 2025

2 Focus area: Berlin-Brandenburg region

The Berlin-Brandenburg region (BBR) represents a complex interplay of urban and rural dynamics and interdependencies, where water and energy demand, agriculture, forestry, nature conservation, and tourism are closely interlinked. Shaped by glacial processes during the Pleistocene, the region is characterised by sandy soils with low water retention capacity, making it particularly vulnerable to hydrological fluctuations such as droughts and groundwater decline. This low water retention is further intensified through an extensive network of artificial drainage channels and straightened river channels. The Havel and Spree rivers, together with a network of lakes and canals, form the backbone of the regional water system, which has been extensively modified over the centuries to support agriculture, urban growth, and industrial activities, including lignite mining. For example, up to 70 percent of Berlin's drinking water, sourced from groundwater, for more than 3.4 million people is extracted via bank filtration from these surface waters (SenUMVK, 2022). Furthermore, the region is home to valuable landscapes for nature conservation and cultural heritage such as the UNESCO Spreewald Biosphere Reserve. However, climate change, urban expansion, and the planned coal phase-out in the Lausitz pose significant challenges, highlighting the need for sustainable water management and integrated supra-regional planning to ensure the future resilience of the BBR (SenUMVK, 2022). Due to the high variability of local extreme events, the region is considered to be particularly vulnerable to the consequences of advancing climate change. Current model projections assume a potential increase in average air temperature of up to 3.5 °C and a decrease in summer precipitation of 10-30% by the end of the century (Cubasch and Kadow, 2019).

3 Methodology

Addressing the complex challenges of climate and water dynamics in the BBR requires input from a broad community of experts. The Research Unit Climate and Water under Change (CliWaC), a transdisciplinary group of 28 project leaders from leading research institutes in the Berlin area, brought together expertise across a wide array of environmental and social sciences. As active researchers in the region, this group of specialists was selected as the reference group for co-producing relevant research questions for the coming decade in the BBR.

The process of the co-production was divided into 3 steps (Figure 1):

- S1 - the input phase: all CliWaC members were invited to provide statements related to their view of current and future water and climate threats in the BBR for the coming decade.
- S2 - the consolidation phase: during this phase, the statements were translated into research questions and evaluated by the community via an online questionnaire
- S3 - the communication phase: the questionnaire answers were analysed and communicated to the reference group for final reflection.

S1 was kicked off during the project meeting in November 2023 in Kremmen (Brandenburg) with 50 project members involved. In the following months, statements were provided by the community (S1). Once all statements had been collected,

https://doi.org/10.5194/egusphere-2025-428
Preprint. Discussion started: 4 April 2025

they were organised and translated into 48 research questions. These research questions were presented to the reference group as a questionnaire, to evaluate their relevance and potential positive impacts on the BBR in the coming decade (S2).

The questionnaire presented to the participants during S2 (see supplements to the paper) contained 48 potential questions divided into the five categories (climate adaptation and resilience; water management; technological solutions and innovation; past, present and future impacts; and governance and public awareness). The evaluation was based on a scale of 1 (irrelevant) to 4 (very relevant). Once all the answers to the questionnaire had been collected (S3), the most relevant questions were selected based on a weighted mean of answers scaled within each category, providing a single relevance grade for each of the 48 questions (supplement material). The top two questions in each of the five categories were selected. The list of 10 questions was shared with the reference group for a final reflection and rephrasing of the propositions.

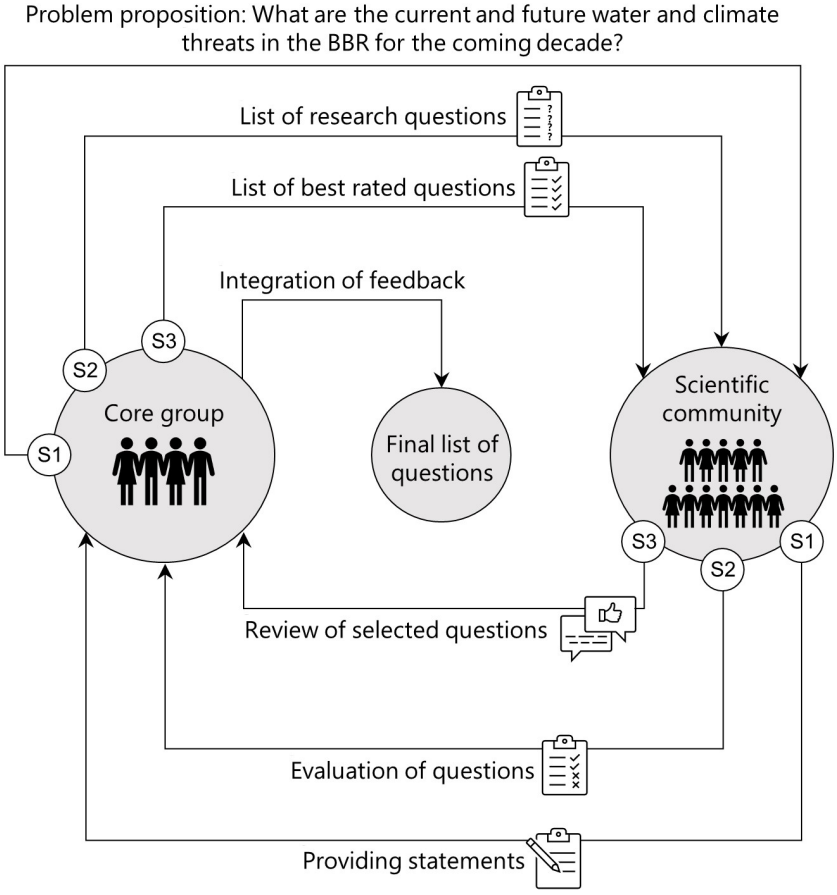

Figure 1. Flowchart of the interactive process of co-production to obtain the list of relevant questions for the Berlin-Brandenburg region on the topic of climate and water.

https://doi.org/10.5194/egusphere-2025-428
Preprint. Discussion started: 4 April 2025

4 Results and discussion

The top questions selected based on the questionnaire responses were compiled into a list with 10 questions, presented in Table 1.

Table 1. List of most relevant scientific questions for the Berlin-Brandenburg region for the coming decade on the topic of Climate and Water.

Category	Question
Category 1 - Climate adaptation and resilience	Q1 - How can ecosystems and agriculture adapt to hydroclimatic extremes expected in the future?
	Q2 - What changes in management and policy can make the Spree catchment more resilient to droughts?
Category 2 - Water management	Q3 - What are the possible scenarios for the Spree catchment and the city of Berlin after the mining phaseout in the Lausitz given accelerating climate change?
	Q4 - What management strategies can be adopted to cope with water scarcity periods in the Berlin-Brandenburg region?
Category 3 - Technological solutions and innovation	Q5 - How feasible is the implementation of a multi-sector impact-based drought monitoring and forecasting system?
	Q6 - To what extent can nature-based solutions be effectively implemented in Berlin (urban) and Brandenburg (rural) to increase resilience and community awareness of climate change and water?
Category 4 - Past, present, and future impacts	Q7 - What other regions have experienced such drastic changes in river flow and what were the long-term impacts? How can the Berlin-Brandenburg region benefit from this knowledge exchange?
	Q8 - How has climate change affected and will affect the multiple urban and rural water services in the Berlin-Brandenburg region?
Category 5 - Governance and public awareness	Q9 - How can individual and community perceptions of extreme events improve impact assessment and monitoring in the Berlin-Brandenburg region?
	Q10 - How can co-creation of water knowledge assist in integrating science, administration, and society to face climate change challenges?

The (BBR) is one of the driest areas in Germany (DWD, 2022) and is susceptible to drought and climate change-related hazards (Brill et al., 2024; Alencar and Paton, 2024; Alencar et al., 2024; Mahmoodi et al., 2024; Somogyvári et al., 2024). The recent 2018-2019 and 2022 droughts in the BBR (Blauhut et al., 2022; Biella et al., 2024) were likely causes of higher

https://doi.org/10.5194/egusphere-2025-428
Preprint. Discussion started: 4 April 2025

perceived relevance of topics related to drought monitoring, management, mitigation, and adaptation present in the list (Q1, Q2, Q4, Q5, Q9). Among these questions, Q1 and Q9 are more general, addressing topics of *extreme events* and *hydroclimatic extremes*, including droughts, floods, wind storms, and heatwaves.

Issues related to changes in mining operations in the Lausitz are also perceived as highly relevant (Q3, Q7). The rapid change in the flow regime of the River Spree, driven by the end of mining operations and the artificial transfer of water resources into the system that provides drinking water to Berlin and the surrounding areas, is a major threat to the city's capacity to meet its water needs in the coming years (Uhlmann et al., 2023). The foreseen decrease in water supply could intensify conflicts in the Berlin-Brandenburg relations (urban-rural). Understanding how climate change has affected these regions and how it will impact water resources and the landscape in the coming years is also considered a pressing issue(Q8).

Focusing on nature-based solutions, Q6 shows that the scientific community considers the design of solutions that integrate practice, community, and nature to be relevant. Berlin fosters blue-green infrastructure (BGI) (SenUMVK, 2022; Warter et al., 2024) through solutions such as green roofs, green façades (Hoffmann et al., 2021), urban trees and grasslands (Kuhlemann et al., 2021; Tams et al., 2024; Kluge and Kirmaier, 2024), and rainwater harvesting (Paton et al., 2023). Integrating BGI into urban and rural landscapes to support sustainable water management is a major challenge and has not yet been explored (Warter et al., 2024). The interest in community participation and awareness is illustrated by the perceived relevance of more transdisciplinary and participatory methods such as co-creation (Q10).

We would like to note that although the scientific community that participated in this assessment is highly diverse (e.g. multiple research fields, age, and career stages), the obtained list presented in Table 1 is not a fully comprehensive summary of the topics currently in focus within the region. However, we can assess seemingly more popular or relevant topics by looking at the top-rated questions (for a full list of the collected questions please see the supplements). We can also see some biases due to local conditions (e.g. regional economic and political characteristics that influence the participants) or particular converging interests of the group being assessed.

Our results reveal a major focus is directed to anthropogenic and profitable landscapes, such as agriculture, forestry, and urban areas. These highly managed ecosystems and landscapes are more strongly disrupted by droughts, leading to cascading impacts (Cavalcante et al., 2024). Solutions to climate change are also perceived to depend on (i) technical and nature-based solutions, such as improved monitoring and forecasting of extreme events and re-engineering of urban and rural spaces to adapt to climate change; and (ii) policy and management adaptations with some level of community involvement.

The motivating question presented in step S1 focused on the next decade for coping with climate change in a limited geographical region. This narrow framework may be the cause for the lack of statements (step S1) and questions (step S2) that tackle more structural issues leading to climate change, such as economic, production, and societal arrangements (Cortinhas et al., 2024). In a next step, a broader audience (beyond the scientific community) and scope should be applied to assess potential cross-cutting research questions with such a structural change perspective.

https://doi.org/10.5194/egusphere-2025-428
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5 Conclusion remarks

This work was based on the premise of identifying what is considered relevant to climate and water sciences in the BBR region for the next decade. This initiative has proven successful, having compiled a comprehensive list of ten timely and overarching questions that seek to tackle hydroclimatic extremes, resources management, adaptation, and academy-society integration. These questions could provide the backbone for framing future climate and water-related research and funding in the region, providing a comprehensive list of priorities for government, funding agencies, and research institutes Drought has been a topic on the research agenda at BBR for a long time.

Nevertheless, only a small fraction of the recommendations have been put into practice, leaving many of the existing (and new) challenges unsolved. Past and current research in the international and regional contexts have called for more integrated strategies for the sustainable use of water and water bodies at regional scales by considering the impacts of climate change, new technologies, socioeconomic change processes, land use change, and extreme events. The survey results also revealed that the issues of extreme events and hydroclimatic extremes, including droughts, the reduced discharge from the Lausitz in the post-mining era, and the nature-based solutions are the most urgent and critical issues to be addressed. The survey also indicates that attention needs to be paid to anthropogenic changes such as environmental pollution, degradation, and land use change.

Our results emphasize the need for continued research to address the climate-water nexus, taking into account natural and human habitats and activities (biodiversity, agriculture, forestry, etc.) and involving many agents and stakeholders. The findings imply a change of perspective in the structure of research and the emergence of new and more collaborative methods, trans-disciplinarity, sharing of resources and information, social science protagonism and community-led science, involving local people for local solutions. The compiled list of ten questions is not exhaustive due to time constraints, under-representation of research areas, and sample size. Nevertheless, it points in a positive and optimistic direction for collective action. We hope the list is the first step and motivation for similar initiatives to identify and solve local-regional problems.

Data availability. Data can be made available upon request.

Author contributions. Conceptualization, methodology, data collection and analysis: PHLA, SA, KN, and MS. *Writing*: The original draft was prepared by a core team composed by: PHLA, SA, KN, and MS. All authors were involved in the reviewing and editing process, offering priceless commentary and suggestions to the original draft: FrB, FB, JD, PF, DJ, NM, CM, SM, KN, EP, TS, DT, FT, TV, SVV, BZ, HZ.

Competing interests. At least one of the (co-)authors is a member of the editorial board of Natural Hazards and Earth System Sciences Journal.

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https://doi.org/10.5194/egusphere-2025-428
Preprint. Discussion started: 4 April 2025

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